

	30	40	50	60	70	80
第1A	1.001	0.998	1.002	1.001	0.997	
第2A	1.000	0.999	0.997	0.999	0.998	
第3C	1.001	0.998	0.999	0.998	0.997	
第1D	1.001	0.997	1.002	0.999	0.998	
第2E	1.000	0.995	1.001	0.999	0.998	
第3F	0.998	0.989	0.996	0.993	0.993	
第4I	0.997	0.986	0.994	0.997	0.991	

【01115】 第3D、第3E、第3F、第3Gはほとんど等しくなっている、第3Iは明らかに高減衰である。以下の表で示される。

【0112】 以下の表は、第3Gの半減期について、他の半減期との相対差が50%以内である場合について示されるべきである。

【0113】

以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。

【0114】

中間層の厚さは、中間層の厚さで示され、中間層は以下の表で示される。

【0115】

本発明は、中間層の厚さは、中間層の厚さで示され、中間層は以下の表で示される。以下の表は、中間層の厚さは、中間層の厚さで示され、中間層は以下の表で示される。

【0116】

【0117】

【0118】

【0119】

第1層の厚さ (μm)	第2層の厚さ (μm)	第3層の厚さ (μm)
第1A	20	20
第1B	20	20
第1C	20	20
第1D	20	20
第1E	20	20

【0120】

以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。

【0121】

【0122】

第1層の厚さ (μm)	第2層の厚さ (μm)	第3層の厚さ (μm)
第1A	20	20
第1B	20	20
第1C	20	20
第1D	20	20
第1E	20	20

【0123】

以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。

【0124】

以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。以下の表は、第3Gの半減期が50%以内である場合について示されるべきである。

【0125】

【0126】

【0127】

【0128】

【0129】

【0130】

【0131】

【0132】

【0133】

【0134】

【0135】

	Jan	Feb	Mar	Apr	May
実入(円)	0.995	1.010	1.013	1.018	0.997×10
実出(円)	1.001	1.039	1.039	1.006	0.917×10
実付(円)	1.011	1.005	1.024	1.006	0.898×10
実引(円)	1.009	1.025	1.017	1.006	0.918×10
実収(円)	0.993	1.003	1.030	1.006	0.912×10

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【0124】
 なるに、例示した銀を所費したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0125】
 【表12】

	Jan	Feb	Mar	Apr	May
実入	1.001	0.997	1.000	0.995	0.997
実出	1.001	0.995	1.000	1.001	0.997
実付	1.000	0.999	1.003	1.001	0.997
実引	1.000	0.999	0.995	0.996	0.997
実収	1.000	0.999	0.999	0.995	0.997

19

【0126】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0127】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0128】
 【表13】

	Jan	Feb	Mar	Apr	May
実入	1.001	0.997	1.000	0.995	0.997
実出	1.001	0.995	1.000	1.001	0.997
実付	1.000	0.999	1.003	1.001	0.997
実引	1.000	0.999	0.995	0.996	0.997
実収	1.000	0.999	0.999	0.995	0.997

20

【0129】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0130】
 【表14】

【0131】
 【表15】

年齢階級 (歳)	人数 (人)	所得 (円)	所得 (円)	所得 (円)
25歳以下	45	900	10	40
26歳以上	1	20	5	2
27歳以上	1.5	50	5	5
28歳以上	75	1500	10	100
29歳以上	150	3000	15	150
30歳以上	150	3000	15	150

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【0132】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0133】
 【表16】

年齢階級 (歳)	人数 (人)	所得 (円)	所得 (円)	所得 (円)
25歳以下	45	900	10	40
26歳以上	1	20	5	2
27歳以上	1.5	50	5	5
28歳以上	75	1500	10	100
29歳以上	150	3000	15	150
30歳以上	150	3000	15	150

20

【0134】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0135】
 【表17】

年齢階級 (歳)	人数 (人)	所得 (円)	所得 (円)	所得 (円)
25歳以下	45	900	10	40
26歳以上	1	20	5	2
27歳以上	1.5	50	5	5
28歳以上	75	1500	10	100
29歳以上	150	3000	15	150
30歳以上	150	3000	15	150

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【0136】
 なるに、例示した銀を、例示したの銀は、各銀を、各銀に付する銀は、各銀に付する。

【0137】
 【表18】

【0138】
 【表19】

22

【図 1】本発明の炭化炭素化合物の炭素原子の配列構造を説明するための図の炭素の 1 原子を

【符号の説明】

101 炭素原子

102 炭素原子の結合点

103 炭素原子の結合点

104 炭素原子の結合点

105 炭素原子の結合点

106 炭素原子の結合点

107 炭素原子の結合点

108 炭素原子の結合点

109 炭素原子の結合点

110 炭素原子の結合点

111 炭素原子の結合点

112 炭素原子の結合点

113 炭素原子の結合点

114 炭素原子の結合点

115 炭素原子の結合点

116 炭素原子の結合点

117 炭素原子の結合点

118 炭素原子の結合点

119 炭素原子の結合点

120 炭素原子の結合点

121 炭素原子の結合点

122 炭素原子の結合点

123 炭素原子の結合点

124 炭素原子の結合点

125 炭素原子の結合点

126 炭素原子の結合点

127 炭素原子の結合点

128 炭素原子の結合点

129 炭素原子の結合点

130 炭素原子の結合点

131 炭素原子の結合点

132 炭素原子の結合点

133 炭素原子の結合点

134 炭素原子の結合点

135 炭素原子の結合点

136 炭素原子の結合点

137 炭素原子の結合点

138 炭素原子の結合点

139 炭素原子の結合点

140 炭素原子の結合点

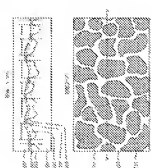
141 炭素原子の結合点

142 炭素原子の結合点

【図 2】炭素原子の

【図 3】

【図 4】



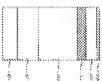
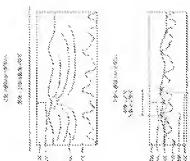
[27] IP 2008-28656 A 2008.10.31

[28]

[29]

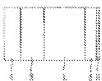
[30]

[31] IP 2008-28657 A 2008.10.31



[32]

[33]



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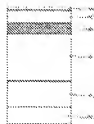
(72)Inventor : TOKAWA MAKOTO
NAKAMURA TETSUO

(54) LAMINATED PHOTOVOLTAIC ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a laminated photovoltaic element which, in further detail, can efficiently collect the energy of an incident light and which has the high photoelectric conversion efficiency of an open voltage and a curvilinear factor with the small influence of a defect, related to the laminated photovoltaic element.

SOLUTION: The photovoltaic element includes a pn junction or a plurality of laminated photovoltaic layers each containing the pn junction. In this photovoltaic element, an island-like intermediate layer is formed at least on one semiconductor layer interface.



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- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.*** shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]

[Claim 1]

A photovoltaic cell which is a photovoltaic cell which carried out the plural laminates of the photoelectromotive-force layer including a PN junction or PIN junction, and is characterized by providing an intermediate layer of island shape in at least one semiconductor layer interface.

[Claim 2]

The lamination type photovoltaic cell according to claim 1, wherein thickness of a portion which makes the circumference of island shape substantially in an intermediate layer of the aforementioned island shape is less than 50% of average thickness.

[Claim 3]

The lamination type photovoltaic cell according to claim 2, wherein average thickness of a portion which makes the circumference of island shape substantially in an intermediate layer of the aforementioned island shape is less than 25% of all the average thickness.

[Claim 4]

The lamination type photovoltaic cell according to claim 2 substantially characterized by a mean area of orthographic projection of island shape of more than $5 \times 10^{-3} \text{ nm}^2$ being below $5 \times 10^{-7} \text{ nm}^2$ in an intermediate layer of the aforementioned island shape.

[Claim 5]

The lamination type photovoltaic cell according to claim 2, wherein the percentage that area of orthographic projection of island shape occupies to a whole surface product substantially in an intermediate layer of the aforementioned island shape is not less than 30% of 80% or less.

[Claim 6]

The lamination type photovoltaic cell according to claim 2, wherein a portion without an intermediate layer exists in an intermediate layer of the aforementioned island shape in a part of portion which makes the circumference of island shape substantially.

[Claim 7]

The lamination type photovoltaic cell according to claim 1 to 6, wherein average thickness of an intermediate layer of the aforementioned island shape is not less than 10 nm 2 micrometers or less.

[Claim 8]

The lamination type photovoltaic cell according to claim 1 to 7 characterized by an average tilt angle of unevenness of Men of the light incidence side being larger than an average tilt angle of unevenness of Men of the opposite hand in an intermediate layer of the aforementioned island shape.

[Claim 9]

The lamination type photovoltaic cell according to claim 1 to 8, wherein an intermediate layer of the aforementioned island shape consists of metallic oxides.

[Claim 10]

The lamination type photovoltaic cell according to claim 1 to 9 to which the aforementioned photoelectromotive-force layer is characterized by at least one copy consisting of non-single-crystal-silicon system semiconductors.

[Claim 11]

The lamination type photovoltaic cell according to claim 1 to 9, wherein the aforementioned photoelectromotive-force layer contains a layer consisting of an amorphous silicon system semiconductor.

[Claim 12]

The lamination type photovoltaic cell according to claim 1 to 9, wherein the aforementioned photoelectromotive-force layer contains a layer consisting of a microcrystal silicon system semiconductor.

[Translation done.]

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3. In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

This invention is concerned with a lamination type photovoltaic cell with at least two or more photoelectromotive-force layers.

[0002]

[Description of the Prior Art]

photoelectromotive-force **** which a photovoltaic cell is equipment which transforms incident light energy into electrical energy, among those is characterized by a solar cell's changing sunlight into electrical energy, and changing the light of a large wavelength band efficiently -- certain ** Therefore, in order to attain high photoelectric conversion efficiency, it is necessary to absorb light without futility over the large whole wavelength zone. The lamination type photovoltaic cell which laminates the photovoltaic cell containing the photoactive layer of a different band gap as one of solving means is known, the element for which, as for this lamination type photovoltaic cell, the band gap used the large photoactive layer relatively at the light incidence side --- or, Arrange the element which made thickness thin relatively and the light of short wavelength is made to absorb, the light of the long wavelength which penetrated the upside element is made to absorb by arranging the element to which the band gap used the small photoactive layer for the bottom of it relatively, or an element with thick thickness, and absorption use of the light is carried out efficiently in a large wavelength band.

[0003]

I hear that an important point needs to introduce into each element a light of a wavelength zone suitable for the photovoltaic cell which has a photoactive layer from which each band gap differs, and there is here. This has a Reason in the available wavelength band of incident light changing with band gaps of the semiconductor with which each photovoltaic cell is used for the photoactive layer. That is, the photon in which energy is lower than a band gap is not absorbed into a semiconductor, and cannot be used. The photon with bigger energy than a band gap, Since the potential energy of the electron which can be given when an electron is excited, although absorption is carried out will be restricted to the size of the band gap, the difference of bandgap energy and photon energy cannot be used. That is, it is important to enter only the light of a shorter wavelength region into the element by the side of the light incidence, and to enter only the light of a long wavelength field in the element under it in a lamination type photovoltaic cell.

[0004]

As one of the solving means of this, an intermediate layer is provided between photovoltaic cells, the method of using as a reflecting layer is known, and there is a method of providing the conductive layer which reflects the light of short wavelength between each element, and penetrates the light of long wavelength (see the patent documents 1 and the nonpatent literature 1.).

[0005]

[Patent documents 1]

JP.S63-77167.A

[Nonpatent literature 1]

YAMAMOTO, Kenji, a "thin-film-polycrystalline-silicon solar cell", applied physics, Japan Society of Applied Physics, common May, 14, the 71st volume, No. 5, p.524-527

[0006]

[Problem to be solved by the invention]

However, when the above reflecting layers were provided as an intermediate layer, there was a case where shunt resistance fell and open circuit voltage (following, Voc) and a curvilinear factor (following, FF) fell. In the case of the usual lamination type cell or a single cell, by defective closure (following, passivation) processing, shunt resistance increases, and FF is recovered, but when providing the above reflecting layers as an intermediate layer, shunt resistance seldom increases but recovery of FF is small.

[0007]

When there were many defects of the cell which is on the lower part especially, the tendency for Voc and FF to fall was suited.

[0008]

Such a phenomenon suited the tendency which appears notably, so that the intermediate layer's resistivity was so low that the intermediate layer's thickness became thick.

[0009]

It is thought that such a phenomenon happens when providing the above reflecting layers as an intermediate layer, and current flows into field inboard via an intermediate layer, it lets a defect pass and the leakage current flows. When producing a photoelectromotive-force layer, by a pinhole or foreign matter adhesion, such a defect is influence of dust etc., produce it, and in a pinhole. The current with which direct contact was carried out, or the intermediate layer and the lower electrode made the alloy from the foreign-matter-adhesion portion depending on the foreign matter, became low resistance, and flowed through the intermediate layer into the field will flow into a defect, and the generated current will be lost.

[0010]

Since it is difficult to make the photovoltaic cell which does not have a defect covering a large area in the case of a photovoltaic cell especially with a large area of a solar cell etc., it is important to reduce the influence by a defect.

[0011]

Although there is the method of closing a defect by the method that a defective part is filled up with resin etc., after laminating to the upper layer, it is difficult to close a lower layer defect.

[0012]

It is possible sufficiently to carry out whether an intermediate layer is made into high resistance as one of the methods for solving such problem. However, if an intermediate layer is made into high resistance, the series resistance between photoelectromotive-force layers will increase, and FF will fall conversely. Since there is a problem that the effect as a reflecting layer is not acquired enough when an intermediate layer is made thin, an intermediate layer's design becomes very difficult.

[0013]

Can cross to all the wavelength zones of incident light, and can perform energy collection efficiently, and current flows into field inboard via an intermediate layer, and this invention lets a defect pass. The fall of the shunt resistance which happens when the leakage current flows, and the fall of Voc and FF are controlled, and it is in providing a photovoltaic cell with high photoelectric conversion efficiency.

[0014]

[Means for solving problem]

This invention persons found out that the fall of shunt resistance and the fall of Voc and FF could be prevented by providing the intermediate layer of island shape, as a result of repeating research wholeheartedly, in order to solve an aforementioned problem. That is, the place made into the main point of this invention is the photovoltaic cell which carried out the plural laminates of the photoelectromotive-force layer including a PN junction or PIN junction, and the photovoltaic cell providing the intermediate layer of island shape in at least one semiconductor

layer interface is provided.

[0015]

Furthermore, this invention includes the following technical contents.

- (1) The thinner one of the thickness of a portion which makes the circumference of island shape is preferred, and less than 50% of its average thickness is preferred.
- (2) It is preferred that the average thickness of a portion which makes the circumference of island shape substantially is less than 25% of all the average thickness.
- (3) the mean area of the orthographic projection of island shape of more than $5 \times 10^{-3} \text{ nm}^2$ is below $5 \times 10^{-7} \text{ nm}^2$ substantially — it is desirable.
- (4) As for the rate that the area of the orthographic projection of island shape occupies to a whole surface product still more nearly substantially, it is preferred that it is [not less than 30%] 80% or less.
- (5) It is still more preferred that a portion without an intermediate layer exists in a part of portion which makes the circumference of island shape substantially.
- (6) As for the average thickness of the intermediate layer of island shape, it is preferred that it is [not less than 10 nm] 2 micrometers or less.
- (7) As for the average tilt angle of unevenness of Men of the light incidence side, in the intermediate layer of island shape, it is preferred that it is larger than the average tilt angle of unevenness of Men of the opposite hand.
- (8) The photoelectromotive-force layer is preferred for this invention, when at least one copy consists of non-single-crystal-silicon system semiconductors.
- (9) The photoelectromotive-force layer is preferred for this invention, when the layer consisting of an amorphous silicon system semiconductor is included.
- (10) The photoelectromotive-force layer is preferred for this invention, when the layer consisting of a microcrystal silicon system semiconductor is included.

[0016]

[Mode for carrying out the invention]

Hereafter, although an embodiment is described to an example for the solar cell which has two layers of photoelectromotive-force layers as a lamination type photovoltaic cell of this invention, this invention is not restricted at all by these and the number of photoelectromotive-force layers can be chosen suitably.

[0017]

First, the concept of this invention is explained.

[0018]

Drawing 1 is a mimetic diagram showing the concept of the intermediate layer of island shape.

(A) — the top view on the surface of an intermediate layer, and (B) — a top view (A) — A-A — ' — it is the shown sectional view. The photoelectromotive-force layer 105 and the intermediate layer 104 of island shape are illustrated by the figure. Generally, the line which connected the point of 50% of thickness here to average thickness since there was no standard of a sea level in material surfaces, although what came out of the island above the water surface, and is isolated was called island is set as a border of an island, and the portion surrounded by this line is expressed as an island, and let that outside be a portion which makes the circumference of an island. In (A), the portion (portion of a slash) which the solid line expressed the boundary 101 of the island and was surrounded as the solid line is the island 102, and the other portion is the portion 103 which makes the circumference of an island. The dotted line expresses 50% of line 106 of average thickness in (B). The portion which the portion which crosses this dotted line forms the boundary 101 of an island, and is above this dotted line is the island 102 (the range of an arrow), and the portion which is downward is the portion 103 which makes the circumference of an island. Although drawing 2 is the same unevenness as a comparative example, it shows the example with thick average thickness. The photoelectromotive-force layer 202 and the intermediate layer 201 are illustrated by the figure. Similarly, 50% of line 203 of average thickness is denoted by the dotted line. This figure shows that there is no portion which crosses a dotted line and there is no portion used as an island.

[0019]

The mimetic diagram of the course of the leakage current in case a defect exists in a photoelectromotive-force layer is shown in drawing 3.

[0020]

(A) is a case where the intermediate layer 301 of the island shape of this invention is used, and the defects 303 are lack of the semiconductor layer by adhesion of a foreign matter etc., a crack, impurity mixing, etc., and it not only has lost the photovoltaic effect, but it becomes a course of the leakage current. The intermediate layer 301 has conductivity suitably, in order to take the photoelectromotive-force layer 302 and good contact, and the leakage current 306 flows also into field inboard. In this case, the portion 304 which makes the circumference of an island is thinner than the portion of the island 305, and, as for this portion, it becomes difficult to flow through the leakage current. Therefore, the range on which a defect has is restricted to the portion of the island 305. As a result, the fall of shunt resistance and the fall of Voc and FF are controlled.

[0021]

(B) is small compared with thickness, although it is a case where a flat intermediate layer is used substantially and unevenness is formed in the surface. In the case of such an intermediate layer, the leakage current 306 flows from a large area, it reaches far and wide, shunt resistance falls, and the influence of the defect 303 leads to the fall of Voc and FF. Although it is possible to make average thickness thin making the leakage current 306 hard to flow through in the case of such an intermediate layer, if average thickness becomes thin, the function as a reflecting layer will fall. Since surface unevenness will also become small relatively if thickness becomes thin, a scattering effect is also no longer acquired. Although it is possible to make another side and resistivity high, in order to take contact in a photoelectromotive-force layer, although based also on average thickness, resistivity cannot be made not much high. Therefore, an intermediate layer's design becomes very difficult.

[0022]

The effect as a reflecting layer is born by the difference in the refractive index in an intermediate layer's interface, and must take into consideration the multiple echo in both interfaces. Since there is interference of light, reflectance changes with wavelength, but generally, reflectance increases, so that average thickness is thick. If an intermediate layer's surface is unevenness, the scattering effect of light will show up, the light path length of a reflected light will be extended, and the increase in short circuit photoelectric current will be seen in an upper photoelectromotive-force matter layer. On the other hand, since the lights to penetrate are also scattered about, also in a lower photoelectromotive-force matter layer, the increase in short circuit photoelectric current is seen. Therefore, the effect as a reflecting layer is mainly controllable by an intermediate layer's average thickness. If unevenness of an island is furthermore chosen suitably, a scattering effect can also be expected, the light path length in the inside of a semiconductor layer will be extended, and the increase in short circuit photoelectric current will be seen in the cell of an intermediate layer's both sides.

[0023]

By the above operation, improvement in photoelectric conversion efficiency is found by making an intermediate layer into the intermediate layer of island shape by control of a fall of Voc by the increase in short circuit photoelectric current, and control of a fall of shunt resistance, and FF. Since it becomes difficult to flow through the leakage current the more the more the periphery of an island is thin, it is still more desirable if the average thickness of the portion which makes the circumference of island shape has turned into less than 25% of all the average thickness. If there is a portion without an intermediate layer, since the leakage current does not flow, it is more preferred that a portion without an intermediate layer exists in a part of portion which makes the circumference of island shape substantially.

[0024]

The wide range is affected by the influence of a defect and the effect made into the intermediate layer of island shape fades, so that the size of an island is large, since the range (range on which a defect has) into which the leakage current flows is restricted in general to the

range of an island. Since the covering nature of the semiconductor layer deposited upwards worsens and makes an upside photoelectromotive-force layer generate a new defect conversely when the area of an island is small, it leads to decline in photoelectric conversion efficiency. Therefore, the mean area of the orthographic projection of island shape has [more than $5 \times 10^3 \text{ nm}^2$] a preferred range below $5 \times 10^7 \text{ nm}^2$. More than $1 \times 10^4 \text{ nm}^2$ is a range below $1 \times 10^7 \text{ nm}^2$ more preferably, and more than $5 \times 10^4 \text{ nm}^2$ is a range below $5 \times 10^6 \text{ nm}^2$ the optimal.

[0025]

If the number of the area x islands of an island becomes fewer (i.e., if the peripheral part of the island increases), since the effect used as island shape fades, not less than 30% of the rate that the area of the orthographic projection of island shape occupies to a whole surface product is desirable. 80% or less is desirable at that in which the effect of the peripheral part of an island decreasing on the other hand if the aforementioned rate is large, and reducing the leakage current fades. Still more preferably, it is not less than 35% of 75% or less, and is not less than 40% of 70% or less the optimal.

[0026]

As for the average thickness of the intermediate layer of island shape, it is preferred that it is [not less than 10 nm] 2 micrometers or less. Since the effect as a reflecting layer is born by the difference in the refractive index in an intermediate layer's interface as stated in the top, an effect will not be acquired if not much thin. Therefore, not less than 10 nm is preferred. Since the short circuit photoelectric current of a lower cell falls in order that the absorption of thickness which exceeds 2 micrometers by an intermediate layer may increase, 2 micrometers or less are preferred. Still more preferably, it is not less than 50 nm 1.5 micrometers or less, and is not less than 100 nm 1 micrometer or less the optimal.

[0027]

As for the average tilt angle of unevenness of Men of the light incidence side, in the intermediate layer of island shape, it is preferred that it is larger than the average tilt angle of unevenness of Men of the opposite hand. With an average tilt angle here, the normal line direction of the curved surface f (X1, Y1, Z1) of a certain position (X1, Y1, Z1) averages the altitude of a substantial substrate, and the angle to make in each position within a field on the curved surface f of an intermediate layer's surface. The angle of inclination can observe AFM etc. easily using the measuring means which can observe the shape of surface type. Since the wavelength of light is targeting about several 100 nm, in measurement, the resolution of about several 10 nm is indispensable for resolution. on the other hand, although the image of an atomic structure level can be observed by progress of the latest technology, from a viewpoint generally called shape of surface type, such an observation means is unnecessary. What is necessary is just to choose the suitable resolution (several nanometers - 10 nm of numbers) which can observe solid surface form substantially.

[0028]

Here, if light enters into a sloping field, refraction resulting from the difference in a refractive index will cut. It is island shape, and if a concavo-convex average tilt angle is large, the angle which carries out optical refraction will become large, and an optical scattering effect will increase. By the way, the way refracted to an angle which is different from Men of the light incidence side in Men of the opposite hand since there is a multiple echo in two interfaces, Men and Men of an opposite hand of the membranous light incidence side, as a reflecting layer as stated also above. It is higher for a scattering effect to have an average tilt angle from which both sides differ, since a scattering effect becomes high.

[0029]

When the spectrum of sunlight is considered, the wavelength ranges which can be used effectively are 300 nm - near 1200 nm in general. It is preferred that short wavelength light is absorbed in the cell of an intermediate layer's upper part, and the light of a long wave penetrates effectively as an intermediate layer, and it is desirable for the transmissivity of 800 nm which is a rule of thumb of long wavelength to be not less than 50 more%. It is not less than 70% still more preferably. It is not less than 80% the optimal.

[0030]

Although a metal ultra-thin film can also be used as an intermediate layer for example, long wavelength light is penetrated and a metallic oxide is preferred for the intermediate layer of the aforementioned island shape as what is moderate resistivity.

[0031]

A photoelectromotive-force layer is preferred for this invention, when at least one copy consists of non-single-crystal-silicon system semiconductors. In the silicon system non single crystal semiconductor, bandgap energy has shifted from the bandgap energy (near 1.4 eV) which can absorb light most efficiently, and it is suitable to apply the intermediate layer of the island shape of this invention using a lamination type photovoltaic cell.

[0032]

The photoelectromotive-force layer is preferred for this invention, when the layer consisting of an amorphous silicon system semiconductor is included. An amorphous silicon system semiconductor has bandgap energy as large as 1.7 eV, and is good to use an amorphous silicon system semiconductor for the light incidence side.

[0033]

The photoelectromotive-force layer is preferred for this invention, when the layer consisting of a microcrystal silicon system semiconductor is included. Its bandgap energy is as small as 1.1 eV, and since the microcrystal silicon system semiconductor can also expect the optical confinement effect, it is good to use a microcrystal silicon system semiconductor for a photoelectromotive-force layer different [light incidence side].

[0034]

Next, the composition and each component of this invention are explained in detail.

[0035]

Drawing 4 is a schematic view showing the section structure of the lamination type photovoltaic cell which is an embodiment of this invention. The light reflection layer 402, the 2nd photoelectromotive-force layer 403, the intermediate layer 404 of island shape, the 1st photoelectromotive-force layer 405, and the transparent electrode 406 are laminated in order on the metal conductive substrate 401. The 1st photoelectromotive-force layer 403 comprises a semiconductor with a larger band gap than the semiconductor of the 2nd photoelectromotive-force layer, or the semiconductor which constitutes the photoactive part of the 1st photoelectromotive-force layer 405 and the 2nd photoelectromotive-force layer 403. The photoactive part is constituted thinly, and it is designed so that the light of a long wavelength region may be absorbed in the 2nd photoelectromotive-force layer 403 in a short wavelength region by the 1st photoelectromotive-force layer 405. The intermediate layer 404 of island shape reflects a part of light, and has the effect of making the light absorption amount of the 1st photoelectromotive-force layer 405 increasing.

[0036]

Drawing 5 is a schematic view showing the section structure of the lamination type photovoltaic cell which are other embodiments of this invention. The transparent electrode 506, the 1st photoelectromotive-force layer 505, the intermediate layer 504 of island shape, the 2nd photoelectromotive-force layer 503, and the conductive light reflection layer 502 are laminated in order on the substrate 501 of translucency electric insulating plates, such as glass. In this case, light incidence is performed from the substrate 501 side which is a translucency insulating substrate.

[0037]

Drawing 6 is a schematic view showing the section structure of the lamination type photovoltaic cell of the same composition as the lamination type photovoltaic cell of this invention shown in drawing 4 except there being no intermediate layer. The light reflection layer 602, the 2nd photoelectromotive-force layer 603, the 1st photoelectromotive-force layer 604, and the transparent electrode 605 are laminated in order on the metal conductive substrate 601.

(Substrate)

Any of a conductive material and an insulating material may be sufficient, and the material which constitutes the substrate used for the lamination type photovoltaic cell of this invention is not

asked about the kind. As a conductive material, metal, such as a plating steel plate, NiCr, stainless steel, aluminum, Cr, Mo, Au, Nb, Ta, V, Ti, Pt, Pb, and Sn, or these alloys are mentioned, for example. As an insulating material, synthetic resins, such as polyester, polyethylene, polycarbonate, cellulose acetate, polypropylene, polyvinyl chloride, a polyvinylidene chloride, polystyrene, and polyamide, or glass, Ceramics Sub-Division, paper, etc. are mentioned. Especially as a metallic base, glass, Ceramics Sub-Division, and polyimide are suitably used as stainless steel and an insulating substrate. When carrying out light incidence from the substrate side, a translucency insulating substrate is used, and especially glass is used suitably.

[0038]

The surface disposition of a substrate may be the texture-ized form used as a smooth side or the rugged surface whose height of thread is a maximum of 0.1-1.0 micrometer. For example, carrying out the etching process of the surface, using an acidic solution as one method of texture-izing the surface of the substrate by stainless steel is mentioned.

[0039]

Although the thickness of a substrate determines suitably that each layer can be laminated to predetermined and it can form a photovoltaic cell in predetermined, when the pliability as a photovoltaic cell is required, the function as a base material should just make it as thin as possible in the range fully demonstrated. However, thickness shall usually be not less than 10 micrometers from [from the manufacture top of a substrate, and handling Kami's field] the field of a mechanical strength.

[0040]

(Reflecting layer)

The deposited film of metal with high reflectance, for example, metal, such as Ag, aluminum, and Cu, and these alloys is used for the reflecting layer used for the lamination type photovoltaic cell of this invention by near-infrared rays from visible light. It is preferred to deposit by methods, such as a vacuum deposition method, sputtering process, etc. and an electrolytic deposition method from solution. The thickness of this reflecting layer is mentioned as thickness for which 10 to 5000 nm was suitable. In order to carry out scattered reflection, it is preferred that the surface is unevenness. In order to increase light volume reflected in a reflecting layer, it is desirable to have a reflective increase layer.

[0041]

ZnO, SnO₂, In₂O₃, ITO, TiO₂, CdO, Cd₂SnO₄, Bi₂O₃, MoO₃, Na_xWO₃, etc. are mentioned to the component of a reflective increase layer. It is preferred for a reflective increase layer to use such materials and to form by methods, such as a vacuum deposition method, sputtering process, an electrolytic deposition method, a CVD method, a spray method, the spin turning-on method, and the DINNGU method. Although the optimal thickness changes with refractive indices in which the material of construction has this reflective increase layer thickness peculiar, 50 nm - 10 micrometers are preferably mentioned as a range of thickness. In order to scatter light, it is preferred that the surface of a reflective increase layer is unevenness. For example, the unevenness based on the grain boundary is generated by deposition conditions in sputtering process.

[0042]

(Photoelectromotive-force layer)

As a semiconductor used for the lamination type photovoltaic cell of this invention, the single crystal of group IV, III-V fellows, II-VI group, and I-III-VI₂ fellows, polycrystal, micro crystallite, and an amorphous substance are used. As group IV, as C, Si, germanium and these alloys, and III-V fellows, AlAs, As AlSb, GaN, GaP, GaAs, GaSb, InP, InAs, and an II-VI group, CuInSe₂ etc. are mentioned as ZnSe, ZnS, ZnTe, CdS, CdSe, CdTe, Cu₂S, and I-III-VI₂ fellows. Especially a silicon system semiconductor is used suitably. As for a form, a single crystal, polycrystal, micro crystallite, and an amorphous substance are used suitably.

[0043]

The photoelectromotive-force layer used for the lamination type photovoltaic cell of this

invention includes pn junction and a pin junction, laminates at least 2 or more ****s of photoelectromotive-force layers, and is constituted. Although constituting using the semiconductor with which materials differ can also constitute each photoelectromotive-force layer from same material, Since the light of short wavelength is easy to be absorbed, the composition which the photoelectromotive-force layer using the material which is easier to absorb short wavelength arranges, and the photoelectromotive-force layer using the material which is easier to absorb long wavelength after that arranges is suitably used for the light incidence side.

[0044]

(Intermediate layer)

For the intermediate layer used for the lamination type photovoltaic cell of this invention, a metal thin film and metallic oxide are used. As a metal thin film, although the deposited film of metal, such as Ag, aluminum, and Cu, or these alloys is used, since there is absorption, a very thin thin film is used. As a metallic oxide, ZnO, SnO₂, In₂O₃, ITO, TiO₂, CdO, Cd₂SnO₄, Bi₂O₃, MoO₃, Na_xWO₃, etc. are mentioned. Indium oxide, the tin oxide, indium tin oxide, and a zinc oxide are used especially suitably.

[0045]

As a metallic oxide, as for an intermediate layer's refractive index, in order to raise reflectance, it is desirable that it is lower than the refractive index of the portion which touches the intermediate layer of a photoelectromotive-force layer.

[0046]

Although it is a formation method of the intermediate layer of island shape, etching is mentioned, for example. First, it is preferred to form an intermediate layer by methods, such as a vacuum deposition method, sputtering process, an electrolytic deposition method, a CVD method, a spray method, the spin turning-on method, and the DINNGU method. The substance to which conductivity is changed may be then added.

[0047]

Then, it can form in island shape by wet etching or dry etching using the etch rate of the grain boundary being large. At this time, hydrogen halide, the gaseous mixture of methane and inactive gas, etc. can be used as dry etching. In wet etching, acid, such as acetic acid, chloride, and nitric acid, can be used. In a described method, since control is difficult, it can also etch by an etch rate's providing a late ultra-thin thin film on an intermediate layer, and making this a mask.

[0048]

It is obtained also by making it condense by heat-treatment after formation by methods, such as a vacuum deposition method, sputtering process, an electrolytic deposition method, a CVD method, a spray method, the spin turning-on method, and the DINNGU method.

[0049]

(Transparent electrode)

The transparent electrode used for the lamination type photovoltaic cell of this invention Indium oxide, Tin oxide, indium tin oxide, a zinc oxide, etc. are mentioned, and it can form by sputtering process, a vacuum deposition method, chemical vapor deposition, the ion plating method, the ion beam method, an ion beam sputtering method, etc. The electric depositing method and dip coating out of the solution consisting of a nitric acid group, an acetic acid group, an ammonia group, etc. and metal ion are also producible. As for the thickness of a transparent electrode, it is preferred to form in the thickness which fulfills the conditions as an antireflection film.

[0050]

(Working example)

Although the suitable working example of this invention is described in detail below based on an accompanying drawing, this invention is not limited to these working examples.

[0051]

(Working example 1)

i layer produced the lamination type photovoltaic cell for which i layer used the zinc oxide layer as an intermediate layer of the pin type photovoltaic cell of intrinsic micro crystallite Si, and

island shape as 1st photoelectromotive-force layer as the pin type photovoltaic cell of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer.

[0052]

In the substrate 401, it exhausted until it used the flat stainless steel (SUS430) generally called BA finishing, it installed in commercial direct-current magnetron sputtering equipment (un-illustrating) and the pressure became below 10^{-3} Pa in 45 mm x 45 mm of every direction, and 0.15-mm-thick form.

[0053]

Then, $30\text{-cm}^3 / \text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. The substrate was not heated, but impressed the direct current power of 120W to the aluminum target of 6 inchphi, and deposited the metal layer of 70-nm aluminum in 90 seconds. Then, substrate temperature was heated at 200 **, electrical connection was changed to the target of the zinc oxide of 6 inchphi, the direct current power of 500W was impressed for 30 minutes, and the reflective increase layer of about 3000-nm zinc oxide was deposited.

[0054]

Drawing 7 is a mimetic diagram showing one form of suitable equipment, in order to produce the semiconductor layer of the lamination type photovoltaic cell of this invention. The system for forming deposit film shown in drawing 7, It mainly comprises the load chamber 701, the microcrystal silicon I type layer chamber 703, the amorphous silicon I type layer RF chamber 704, the n type layer RF chamber 702 and the p type layer RF chamber 705, and the unloading chamber 706. Between each chamber, it dissociates so that each material gas may not be mixed with the gate valves 707, 708, 709, 710, and 711.

[0055]

The microcrystal silicon I type layer chamber 703 comprises the heater 712 and the plasma-CVD room 713 for substrate heating. The RF chamber 702 the deposition room 715 the heater 714 for n type layer deposition, and for n type layer deposition, The RF chamber 704 has the deposition room 719 of the for the heater 718 for p type layer deposition, and for p type layer deposition in the RF chamber 705 for the deposition room 717 the heater 716 for I type layer deposition, and for I type layer deposition. A substrate is attached to the substrate holder 621 and moves with the roller which drives the rail 720 top from the outside. Micro crystallite is formed at the plasma-CVD room 713. As for micro crystallite, a microwave plasma CVD method or VHF plasma CVD method is used.

[0056]

Such a system for forming deposit film was used, and the semiconductor layer was deposited on the basis of the predetermined film formation condition in each layer as shown in Table 1.

[0057]

[Table 1]

		成膜ガス ($\text{cm}^3/\text{min}(\text{normal})$)				電力密度 (W/cm^2)		圧力 (Pa)	基板 温度 ($^{\circ}\text{C}$)	膜厚 (nm)
		SiH_4	H_2	PH_3 (2%H 希釈)	BF_3 (2%H 希釈)	RF	VHF			
第1 電力層 光起	n1	2	48	0.5		0.04		130	225	10
	i1	2	48			0.04		150	210	500
	p1	0.025	35		1	1.2		270	165	5
第2 電力層 光起	n2	2	48	0.5		0.04		130	225	20
	i2	25	750				0.2	40	250	2000
	p2	0.025	35		1	1.2		270	165	5

[0058]

First, according to Table 1, the 2nd photoelectromotive-force layer was deposited in the following procedures on the substrate 401 which deposited the reflecting layer 402. The substrate 401 is set to the substrate holder 721, and it sets on the rail 720 of the load chamber 701. And the inside of the load chamber 701 is exhausted to the degree of vacuum of hundreds of or less mPa.

[0059]

Next, the gate valve 707 is opened and the substrate holder 721 is moved to the n type layer deposition room 715 of the chamber 702. Where each gate valve 707, 708, 709, 710, and 711 is closed, a n type layer is deposited on predetermined thickness with predetermined material gas. After fully exhausting, the gate valve 708 is opened, the substrate holder 721 is moved to the deposition chamber 703, and the gate valve 708 is closed.

[0060]

A substrate is heated to predetermined substrate temperature with the heater 712, initial-complement introduction of the predetermined material gas is carried out, it is made a predetermined degree of vacuum, predetermined microwave energy or VHF energy is introduced to the deposition room 713, plasma is generated, and a microcrystal silicon I type layer is deposited on a substrate at predetermined thickness. The chamber 703 is fully exhausted, the gate valves 709 and 710 are opened, and the substrate holder 721 is moved to the chamber 705 from the chamber 703.

[0061]

After moving the substrate holder 721 to the p type layer deposition room 719 of the chamber 705, a substrate is heated to a desired temperature with the heater 718. Only a predetermined flow supplies the material gas for p type layer deposition to the deposition room 719. RF energy is introduced into the deposition room 719, maintaining to a predetermined degree of vacuum, and a p type layer is deposited on desired thickness.

[0062]

After fully exhausting the deposition room 719 like the above, the gate valve 711 is opened and the substrate holder 721 which set the substrate 401 which the semiconductor layer deposited is moved to the unloading chamber 706.

[0063]

All gate valves are closed, nitrogen gas is enclosed into the unloading chamber 706, and

substrate temperature is cooled. Then, the extraction valve of the unloading chamber 706 is opened and the substrate holder 721 is taken out.

[0064]

Next, it exhausted until it installed in commercial direct-current magnetron sputtering equipment (un-illustrating) and the pressure became below 10^{-3} Pa. in order to remove the substrate 401 produced from the substrate holder 721 to the 2nd photoelectromotive-force layer and to form an intermediate layer.

[0065]

Then, $30\text{-cm}^3 / \text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. Then, substrate temperature was heated at 200°C , electrical connection was changed to the target of the zinc oxide of 6 inchphi, the direct current power of 100W was impressed for 25 minutes, and about 500-nm zinc oxide layer was deposited. Then, $30\text{-cm}^3 / \text{min}$ (normal) supply of ARUGONGA r SU were carried out, and the pressure was held to 2×10^{-1} Pa. Substrate temperature was heated at 200°C , electrical connection was changed to the zinc oxide target which contains chromium of 6 inchphi 5weight %, the direct current power of 50W was impressed for 1 minute, and the zinc oxide layer by which about 10-nm chromium was added was deposited. Then, it took out and etched into 10weight % of the acetic acid solution by dipping for 40 seconds. And it cleaned ultrasonically using isopropyl alcohol and was made to dry in oven.

[0066]

Next, it produced so that a pin type amorphous Si:H photovoltaic cell might be again described below as 1st photoelectromotive-force layer on the substrate 401 which the above-mentioned intermediate layer deposited using the system for forming deposit film 700.

[0067]

An n type layer is deposited on predetermined thickness on condition of predetermined like the above. After fully exhausting, the gate valves 708 and 709 were opened, the substrate holder 721 was moved to the deposition chamber 704, and the gate valves 708 and 709 were closed.

[0068]

A substrate is heated to predetermined substrate temperature with the heater 716, initial-complement introduction of the predetermined material gas is carried out, it is made a predetermined degree of vacuum, predetermined RF energy is introduced to the deposition room 717, plasma is generated, and an amorphous Si:H I type layer is deposited on a substrate at predetermined thickness. The chamber 704 was fully exhausted, the gate valve 710 was opened, and the substrate holder 721 was moved to the chamber 705 from the chamber 704.

[0069]

The p type layer was deposited on predetermined thickness on condition of predetermined like the above.

[0070]

After fully exhausting the deposition room 719 like the above, the gate valve 711 was opened and the substrate holder 721 which set the substrate 401 which the semiconductor layer deposited was moved to the unloading chamber 706.

[0071]

The substrate holder 721 was taken out from the inside of the unloading chamber 706 like the above.

[0072]

Next, attach a substrate to the surface of the anode of DC magnetron sputtering equipment, and the circumference of a sample is covered with the mask of stainless steel. Sputtering of the indium tin oxide was carried out to the field of $40\text{ mm} \times 40\text{ mm}$ of center sections as a transparent electrode using the target which consists of 10weight % of tin oxide, and 90weight % of indium oxide.

[0073]

Deposition conditions as the substrate temperature of 170°C , and inactive gas Flow 3 of 50

cm³ / min of argon (normal). It deposited so that thickness might be set to 70 nm in about 100 seconds by 0.5 cm of oxygen gas³ / min (normal). pressure 300mPa of the deposition interior of a room, and amount of power supplies 0.2 W/cm² per unit area of a target. Membranous thickness was made into predetermined thickness by carrying out measuring of the relation with assembly time, and forming it on the same conditions, beforehand. In this way, the produced sample was used as "the fruit 1."

[0074]

(Comparative example 1)

In an intermediate layer's production, 30-cm³ / min (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. Then, substrate temperature was heated at 200 **, electrical connection was changed to the target of the zinc oxide of 6 inchphi, the direct current power of 100W was impressed for 15 minutes, and about 300-nm zinc oxide layer was deposited. Thus, by the same procedure as the working example 1, the photovoltaic cell was produced except having produced the intermediate layer. In this way, the produced sample was made into "the ratio 1."

[0075]

First, the working example 1 and the comparative example 1 estimated the intermediate layer's thickness distribution using the sample for intermediate-layer surface observation which even the intermediate layer produced. AFM (Nanopics 1000 by atomic force microscope Seiko Instruments) was used for surface type-like observation. Average thickness observed and asked for the section by TEM (product JEMmade from transmission electron microscope JEOL-4000EX). The procedure was calculated from deciding an intermediate-layer portion, asking for an intermediate layer's thickness from a cross section image, and averaging it by the light and darkness of an image, from the observed cross section image, in a range of observations. Evaluation of thickness distribution observes the AFM image before following an intermediate layer first using the sample for surface observation, and observes the intermediate-layer surface of the same place as origin for marking by AFM. Then, some cross section parts of this range are observed by TEM, and it asks for the thickness of this portion. From this result and two AFM images, it calculated and surface thickness distribution was searched for. The range of observations was performed by 20 micrometer**, and resolution was performed by 512x512 points. 20 measurement was observed at random and it checked that the almost same result was obtained in a field.

[0076]

The thickness of the portion which the intermediate layer is making the form of island shape and into which he makes the circumference of island shape in working example 1 was less than 50% of average thickness. It checked that the zinc oxide layer which contains chromium deposited for the use of the mask from the greatest thickness being thinner than the thickness deposited in the sputtering was removed. Furthermore, average thickness was 300 nm.

[0077]

It received and not the island shape of what has unevenness to an intermediate layer in the comparative example 1 but less than 50% of portion of average thickness could not be found. Average thickness was 300 nm.

[0078]

In this way, YSS-150 by Yamashita electrical incorporated company was used about a total of ten samples produced by the working example 1 and the comparative example 1, and the spectrum of AM1.5, and where light irradiation is carried out by intensity 100 mW/cm², the current potential characteristic was measured. Short circuit current density [J_{sc} (mA/cm²)], open circuit voltage [$V_{oc}(V)$], a music sex factor [FF], and photoelectric conversion efficiency [η (%)] were searched for from the measured current potential characteristic.

[0079]

The volt ampere characteristic in the dark condition of a sample was measured, and it asked for shunt resistance [R_{sh} (Komegacm²)] from inclination to near the starting point.

[0080]

What summarized the ratio (real 1 / ratio 1) of the working example [as opposed to a comparative example for such weighted solidity] is shown in Table 2.

[0081]

[Table 2]

	Jsc	FF	Voc	Eff.	Rsh
実1/比1	1.001	1.032	1.017	1.061	5.12×10^6

[0082]

Compared with the ratio 1, both Jsc FF Voc and Rsh have improved and the fruit 1 showed high photoelectric conversion efficiency.

[0083]

The reliability trial was done as follows. The sample was supplied to the high-humidity/temperature tub and it held to +85 °C and 85% of relative humidity. During this examination, impressing the reverse bias 0.85V to the sample was continued for 20 hours. Then, with extraction and nature, after carrying out dry cooling enough, the volt ampere characteristic was measured. Each characteristic is a relative value over an initial value, and is shown in Table 3.

[0084]

[Table 3]

	Jsc	FF	Voc	Eff.	Rsh
実1	1.001	0.996	1.003	1.000	0.997
比1	0.997	0.986	0.994	0.977	0.321

[0085]

As for the fall of shunt resistance, the fruit 1 was hardly seen by a reliability trial. On the other hand, in the ratio 1, shunt resistance fell rather than the first stage. Voc and FF mainly fell, and decline in photoelectric conversion efficiency was seen.

[0086]

Even if the defect occurred in the photovoltaic cell with the intermediate layer of the island shape of this invention from the above thing, the influence of a defect did not attain to field inboard, but it turned out that initial photoelectric conversion efficiency is good and reliable.

[0087]

(Working example 2)

As 1st photoelectromotive-force layer, as the pin type photoelectromotive-force layer of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer, i layer changed the manufacturing conditions of the lamination type photovoltaic cell for which i layer used the zinc oxide layer as the pin type photoelectromotive-force layer of intrinsic micro crystallite Si, and an intermediate layer of island shape, and produced four samples.

[0088]

Produce on the same conditions as the working example 1 except an intermediate layer, and an intermediate layer's manufacturing conditions each an intermediate layer's average thickness 300 nm in order to arrange. The sample from which the average thickness of a portion which makes the circumference of an island differs was obtained by adjusting the assembly time of a zinc oxide layer, and adjusting the thickness before etching, and adjusting the concentration and

etching time of an acetic acid solution. The sample obtained in this way was made into "real 2A", "real 2B", "real 2C", and "real 2D."

[0089]

The deposition conditions and the etching condition of a zinc oxide layer are summarized in Table 4. and are shown.

[0090]

[Table 4]

	堆積時間 (min)	膜厚 (nm)	酢酸濃度 (重量%)	エッチング時間 (s)
実2A	25	500	10	40
実2B	27	540	8	60
実2C	30	600	5	90
実2D	32	640	5	110

[0091]

The result of having estimated the intermediate layer's thickness distribution as the working example 1 similarly is shown in Table 5. Here, with the average film parameter of the periphery of an island, the average thickness of a portion which makes the circumference of an island is broken by all the average thickness.

[0092]

[Table 5]

	島の周辺部の平均膜厚比(%) [島の周辺部の平均膜厚/全平均膜厚]
実2A	35
実2B	24
実2C	16
実2D	16

[0093]

The thickness of the portion which the intermediate layer is making the form of island shape and into which any sample makes the circumference of island shape was less than 50% of average thickness. The average thickness of any sample was about 300 nm. Any sample checked that the zinc oxide layer which contains chromium deposited for the use of the mask from the greatest thickness being thinner than the thickness deposited in the sputtering was removed. Although the intermediate layer had covered real 2A, real 2B, and real 2C over the whole surface, a part of real 2D had a portion without an intermediate layer.

[0094]

Next, the current potential characteristic of the produced optoelectric transducer was measured like the working example 1. The result is shown in Table 6. A relative value with the comparative example 1 shows a result.

[0095]

[Table 6]

	Jsc	FF	Voc	Eff.	Rsh
実2A/比1	1.011	1.032	1.017	1.061	5.12×10^2
実2B/比1	1.012	1.039	1.020	1.072	7.25×10^3
実2C/比1	1.009	1.041	1.021	1.072	9.89×10^2
実2D/比1	1.011	1.045	1.025	7.083	1.35×10^2

[0096]

The reliability trial was done like the working example 1. Each characteristic is a relative value over an initial value, and is shown in Table 7.

[0097]

[Table 7]

	Jsc	FF	Voc	Eff.	Rsh
実2A	1.001	0.996	1.003	1.000	0.997
実2B	1.000	0.997	1.003	1.000	0.998
実2C	1.000	0.995	1.005	1.000	0.998
実2D	1.000	0.999	1.002	1.001	0.998
比1	0.997	0.986	0.994	0.977	0.321

[0098]

As for no real 2A, B, C, and D, the fall of shunt resistance was almost seen by the reliability trial, but photoelectric conversion efficiency was maintaining the early value.

[0099]

From the above result, rather than the working example 2A, shunt resistance has improved more and Voc and FF acted as Kougami of working-example 2B, 2C, and the 2D more. Therefore, when the average thickness of the periphery of an island was less than 25% of all the average thickness, higher photoelectric conversion efficiency was able to be acquired. From shunt resistance having improved and Voc and FF having improved further, rather than real 2C, real 2D was able to acquire still higher photoelectric conversion efficiency, when a portion without an intermediate layer existed in a part of portion which makes the circumference of island shape.

[0100]

(Working example 3)

As 1st photoelectromotive-force layer, as the pin type photoelectromotive-force layer of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer, i layer changed the manufacturing conditions of the lamination type photovoltaic cell for which i layer used the zinc oxide layer as the pin type photoelectromotive-force layer of intrinsic micro crystallite Si, and an intermediate layer of island shape, and produced six samples.

[0101]

Producing on the same conditions as the working example 1 except the intermediate layer, the intermediate layer's manufacturing conditions obtained the sample from which the mean area of an island differs by changing the assembly time and deposition temperatures of a zinc oxide layer

by which chromium used as a mask was added. The sample obtained in this way was set to "real 3A", "real 3B", "real 3C", "real 3D", "real 3E", and "real 3F."

[0102]

The deposition conditions of the zinc oxide layer by which chromium was added are collectively shown in Table 8.

[0103]

[Table 8]

	堆積時間 (min)	膜厚 (nm)	堆積温度 (°C)
実3A	1.0	10	200
実3B	0.6	6	250
実3C	0.7	7	250
実3D	1.4	14	150
実3E	1.7	17	100
実3F	1.8	18	50

[0104]

The result of having estimated the intermediate layer's thickness distribution as the working example 1 similarly is shown in Table 9. The mean area of an island divides the area aggregate of the orthographic projection of an island by the number of islands here. The mean area was determined by calculating the area of the portion of an island and \times (ing) with the number of an island from the acquired thickness distribution.

[0105]

[Table 9]

	島の平均面積
実3A	150000nm ²
実3B	4100nm ²
実3C	5000nm ²
実3D	4.6μm ²
実3E	50μm ²
実3F	71μm ²

[0106]

The thickness of the portion which the intermediate layer is making the form of island shape and into which any sample makes the circumference of island shape was less than 50% of average thickness. The average thickness of any sample was about 300 nm. Any sample checked that the zinc oxide layer which contains chromium deposited for the use of the mask from the greatest thickness being thinner than the thickness deposited in the sputtering was removed.

[0107]

Next, the current potential characteristic of the produced optoelectric transducer was measured like the working example 1. The result is shown in Table 10. A relative value with the comparative example 1 shows a result.

[0108]

[Table 10]

	Jsc	FF	Voc	Eff.	Rsh
実3A/比1	1.011	1.032	1.017	1.061	5.12×10^{-2}
実3B/比1	1.013	1.011	1.005	1.029	2.29×10^1
実3C/比1	1.012	1.027	1.015	1.055	2.55×10^2
実3D/比1	1.008	1.028	1.016	1.053	2.43×10^2
実3E/比1	1.010	1.025	1.014	1.050	9.76×10^1
実3F/比1	1.009	1.015	1.003	1.027	9.89×10^0

[0109]

Photoelectric conversion efficiency cut real 3B and real 3F low a little rather than real 3A, real 3C, real 3D, and real 3E. The reliability trial was done like the working example 1. Each characteristic is a relative value over an initial value, and is shown in Table 11.

[0110]

[Table 11]

	Jsc	FF	Voc	Eff.	Rsh
実3A	1.001	0.996	1.003	1.000	0.997
実3B	1.000	0.996	0.997	0.993	0.818
実3C	1.001	0.998	0.999	0.998	0.987
実3D	1.000	0.997	1.002	0.999	0.988
実3E	1.000	0.995	1.004	0.999	0.998
実3F	0.998	0.989	0.996	0.983	0.673
比1	0.997	0.986	0.994	0.977	0.321

[0111]

Some fall was seen although real 3A, real 3B, real 3C, real 3D, and real 3E hardly fell, and real 3F has improved rather than the ratio 1.

[0112]

The result showed above that below 50-micrometer² had a more preferred mean area of the orthographic projection of an island above 5000-nm² in the intermediate layer of island shape.

[0113]

(Working example 4)

As 1st photoelectromotive-force layer, as the pin type photoelectromotive-force layer of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer, i layer changed the

manufacturing conditions of the lamination type photovoltaic cell for which i layer used the zinc oxide layer as the pin type photoelectromotive-force layer of intrinsic micro crystallite Si, and an intermediate layer of island shape, and produced five samples.

[0114]

Except the intermediate layer, it produced on the same conditions as the working example 1, and the intermediate layer produced in the following production procedures.

[0115]

300 nm in order to arrange, the intermediate layer's manufacturing conditions made assembly time of the zinc oxide layer 25 minutes, and deposited each the intermediate layer's average thickness on 500 nm. [as well as the working example 1] Then, $30\text{-cm}^3/\text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to $2 \times 10^{-4}\text{Pa}$. Substrate temperature was made into the room temperature, electrical connection was changed to the silver target, the direct current power of 50W was impressed for 40 seconds, and the 20-nm silver of 6 inchphi was deposited. Then, the metal thin film was made to condense by heating to a predetermined temperature. Then, it took out and etched into 10weight % of the acetic acid solution by dipping predetermined time. And it cleaned ultrasonically using isopropyl alcohol and was made to dry in oven.

[0116]

The sample obtained in this way was set to "real 4A", "real 4B", "real 4C", "real 4D", and "real 4E."

[0117]

Heat-treatment of a silver film and the conditions of etching are summarized in Table 12, and are shown.

[0118]

[Table 12]

	加熱温度 (°C)	加熱時間 (min)	エッチング時間 (s)
実4A	260	7	30
実4B	220	10	35
実4C	180	20	55
実4D	120	20	70
実4E	100	20	70

[0119]

The result of having estimated the intermediate layer's thickness distribution as the working example 1 similarly is shown in Table 13. Here, with the rate that the area of the orthographic projection of island shape occupies to a whole surface product, the area of the orthographic projection of island shape is broken by a whole surface product.

[0120]

[Table 13]

	島状の正射投影の面積が 全面積に占める割合(%)
実4A	24
実4B	30
実4C	56
実4D	80
実4E	86

[0121]

The thickness of the portion which the intermediate layer is making the form of island shape and into which any sample makes the circumference of island shape was less than 50% of average thickness. The average thickness of any sample was about 300 nm. From the greatest thickness being thinner than the thickness deposited in the sputtering, any sample checked that the silver film deposited for the use of the mask was removed.

[0122]

Next, the current potential characteristic of the produced optoelectric transducer was measured like the working example 1. The result is shown in Table 14. A relative value with the comparative example 1 shows a result.

[0123]

[Table 14]

	Jsc	FF	Voc	Eff.	Rsh
実4A/比1	0.995	1.010	1.013	1.018	9.09×10^1
実4B/比1	1.007	1.039	1.019	1.066	5.14×10^2
実4C/比1	1.011	1.035	1.021	1.068	6.89×10^2
実4D/比1	1.009	1.023	1.017	1.050	3.89×10^2
実4E/比1	0.999	1.005	1.002	1.006	7.12×10^1

[0124]

The reliability trial was done like the working example 1. Each characteristic is a relative value over an initial value, and is shown in Table 15.

[0125]

[Table 15]

	Jsc	FF	Voc	Eff.	Rsh
実4A	1.001	0.997	1.000	0.998	0.995
実4B	1.001	0.996	1.004	1.001	0.997
実4C	1.000	0.998	1.003	1.001	0.998
実4D	1.000	0.995	1.001	0.996	0.996
実4E	1.000	0.989	0.998	0.987	0.778
比1	0.997	0.986	0.994	0.977	0.521

[0126]

As for no real 4A, real 4B, real 4C, and real 4D, the fall of shunt resistance was almost seen by the reliability trial. On the other hand, some fall was seen although real 4E has improved from the ratio 1.

[0127]

The rate that the area of the orthographic projection of island shape occupies from a result to a whole surface product in the intermediate layer of island shape was understood above that 80% or less is more preferred at not less than 30%.

[0128]

(Working example 5)

As 1st photoelectromotive-force layer, as the pin type photoelectromotive-force layer of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer, manufacturing conditions changed the lamination type photovoltaic cell for which i layer used the zinc oxide layer as the pin type photoelectromotive-force layer of intrinsic micro crystallite Si, and an intermediate layer of island shape, and i layer carried out 6 sample production.

[0129]

The sample from which average thickness differs was obtained by producing on the same conditions as the working example 1 except an intermediate layer, adjusting the assembly time of a zinc oxide layer, adjusting the thickness before etching, in order that an intermediate layer's manufacturing conditions may change an intermediate layer's average thickness, and adjusting the concentration and etching time of an acetic acid solution. The sample obtained in this way was set to "real 5A", "real 5B", "real 5C", "real 5D", "real 5E", and "real 5F."

[0130]

The deposition conditions and the etching condition of a zinc oxide layer are summarized in Table 16, and are shown.

[0131]

[Drawing 16]

	堆積時間 (min)	膜厚 (nm)	酢酸濃度 (重量%)	エッチング時間 (s)
実5A	25	500	10	40
実5B	1	20	5	3
実5C	1.3	26	5	5
実5D	75	1500	10	100
実5E	120	2400	15	130
実5F	150	3000	15	150

[0132]

The result of having estimated the intermediate layer's thickness distribution as the working example 1 similarly is shown in Table 17.

[0133]

[Table 16]

	平均膜厚 (nm)
実5A	300
実5B	8
実5C	10
実5D	900
実5E	2000
実5F	2600

[0134]

When any sample evaluated the intermediate layer's thickness distribution, the peripheral part of the island was less than 50% of average thickness. Any sample checked that the zinc oxide layer which contains chromium deposited for the use of the mask from the greatest thickness being thinner than the thickness deposited in the sputtering was removed.

[0135]

(Comparative example 5)

By the same procedure as the working example 1, the photovoltaic cell was produced for the photovoltaic cell without an intermediate layer like drawing 6. In this way, the produced sample was made into "the ratio 5."

[0136]

The current potential characteristic of the produced optoelectric transducer was measured like the working example 1. The result is shown in Table 18. A relative value with the comparative example 5 shows a result.

[0137]

[Table 17]

	Jsc	FF	Voc	Eff.	Rsh
実5A/比5	1.043	0.997	1.002	1.042	7.25×10^{-1}
実5B/比5	1.005	0.999	0.999	1.003	8.25×10^{-1}
実5C/比5	1.021	1.001	1.001	1.023	9.89×10^{-1}
実5D/比5	1.049	0.987	0.999	1.034	6.35×10^{-1}
実5E/比5	1.034	0.989	0.997	1.020	6.17×10^{-1}
実5F/比5	1.003	0.998	0.999	1.000	4.23×10^{-1}

[0138]

The reliability trial was done like the working example 1. Each characteristic is a relative value over an initial value, and is shown in Table 19.

[0139]

[Table 18]

	Jsc	FF	Voc	Eff.	Rsh
比5	1.001	0.998	1.000	0.999	0.999
実5A	1.001	0.996	1.004	1.001	0.997
実5B	1.000	0.997	1.003	1.000	0.998
実5C	1.000	0.996	1.002	0.998	0.999
実5D	0.998	0.999	1.002	0.999	0.998
実5E	1.000	0.999	1.001	1.000	0.997
実5F	0.999	0.999	1.000	0.998	0.998

[0140]

As for real 5A, real 5B, real 5C, real 5D, real 5E, real 5F, and the ratio 5, the fall of shunt resistance was hardly looked at by each by a reliability trial.

[0141]

The spectral sensitivity characteristic was measured using Jasco Corporation YQ-250BX. The spectral sensitivity characteristic of the 1st photoelectromotive-force layer of each lamination type photovoltaic cell and the 2nd photoelectromotive-force layer was measured as follows. The spectral sensitivity characteristic of the 1st photoelectromotive-force layer irradiates with the bias light of the wavelength zone which impresses the bias voltage corresponding to the electromotive force which the 2nd photoelectromotive-force layer makes a lamination type photovoltaic cell generate at the time of light irradiation, and is mainly absorbed by the 2nd photovoltaic cell. The spectral sensitivity characteristic was measured by irradiating with the reference beam by which the spectrum was carried out, and observing the generating current at that time. The spectral sensitivity characteristic of the 2nd photoelectromotive-force layer impressed the bias voltage corresponding to the electromotive force of the 1st photoelectromotive-force layer like the 1st photoelectromotive-force layer, irradiated with the bias light of the wavelength zone mainly absorbed in the 1st photoelectromotive-force layer, and

measured the spectral sensitivity characteristic in this state.

[0142]

Furthermore, the short circuit photoelectric current of each photovoltaic cell was calculated from this spectral sensitivity characteristic. The short circuit photoelectric current of the 1st photoelectromotive-force layer calculated the current value of the 1st photoelectromotive-force layer by having collapsed the spectral intensity of sunlight in the spectral sensitivity spectrum of the 1st photoelectromotive-force layer measured previously. The short circuit photoelectric current of the 2nd photoelectromotive-force layer calculated the short circuit photoelectric spectrum of the 2nd photoelectromotive-force layer and the spectral intensity of sunlight which were measured previously.

[0143]

A result is shown in Table 20 by the ratio to the comparative example 5 about six samples of the working example 5.

[0144]

[Table 19]

	第1の光起電力層	第2の光起電力層	合計
実5A/比5	1.043	1.011	1.027
実5B/比5	1.005	1.000	1.002
実5C/比5	1.021	1.005	1.013
実5D/比5	1.049	1.021	1.035
実5E/比5	1.068	0.993	1.032
実5F/比5	1.055	0.966	1.017

[0145]

Any sample is increasing the short circuit photoelectric current of the 1st photoelectromotive-force layer from the ratio 5. On the other hand, although the short circuit photoelectric current of the 2nd photoelectromotive-force layer is increasing whether real 5A, real 5B, real 5C, and real 5D change, it is decreasing about real 5E and real 5F. This result shows that the effect as a reflecting layer seldom shows up, when thickness is thinner than 10 nm. If average thickness becomes thick, in order that the penetration of the light to the 2nd photoelectromotive-force layer may decrease, it turns out that the short circuit photoelectric current of the 2nd photoelectromotive-force layer decreases. Furthermore average thickness exceeds 2.0 micrometers, or it becomes and decreases.

[0146]

There is almost no effect which short circuit photoelectric current of real 5B seldom increases, but the intermediate layer of the island shape of this invention establishes from the above result. Although real 5F has an intermediate layer of the island shape of this invention, the penetration of light decreases to the 2nd photoelectromotive-force layer, and the short circuit photoelectric current of an element seldom increases, but the effect of providing the intermediate layer of the island shape of this invention is seldom seen. On the other hand, short circuit photoelectric current of real 5A, real 5C, real 5D, and real 5E increased, and their photoelectric conversion efficiency improved. Therefore, the intermediate layer's average thickness was able to acquire higher photoelectric conversion efficiency in [not less than 10 nm] 2.0 micrometers.

[0147]

(Working example 6)

As 1st photoelectromotive-force layer, as the pin type photovoltaic cell of intrinsic amorphous Si:H, and 2nd photoelectromotive-force layer, i layer changed the manufacturing conditions of the pin type photovoltaic cell of intrinsic micro crystallite Si, and the lamination type photovoltaic cell which used the zinc oxide layer as an intermediate layer of island shape, and i layer produced three samples.

[0148]

It produced on the same conditions as the working example 1 except the intermediate layer. The intermediate layer produced in the following production procedures.

[0149]

It exhausted until it installed in commercial direct-current magnetron sputtering equipment (un-illustrating) and the pressure became below 10^{-3} Pa, since an intermediate layer was deposited.

[0150]

Then, $30\text{-cm}^3 / \text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. Then, substrate temperature was heated at 150°C , electrical connection was changed to the target of the zinc oxide of 6 inchphi, the direct current power of 100W was impressed for 130 minutes, and about 2600-nm zinc oxide layer was deposited. Then, $30\text{-cm}^3 / \text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. Substrate temperature was heated at 150°C , electrical connection was changed to the indium oxide target of 6 inchphi, predetermined carried out time impression of the direct current power of 10W, and indium oxide of predetermined thickness was deposited.

[0151]

Then, it took out and etched into the solution of hydrochloric acid of predetermined concentration by dipping predetermined time. And it cleaned ultrasonically using isopropyl alcohol and was made to dry in oven.

[0152]

The thickness of indium oxide used as a mask was changed, and three samples of "real 6A", "real 6B", and the "fruit 56" were obtained. The deposition conditions and the etching condition of indium oxide are collectively shown in Table 21.

[0153]

[Table 20]

	堆積時間 (min)	膜厚 (nm)	塩酸濃度 (重量%)	エッチング時間 (s)
実6A	1.0	10	1.0	100
実6B	0.6	6	0.8	150
実6C	0.7	7	0.6	160

[0154]

(Comparative example 6)

In an intermediate layer's production, $30\text{-cm}^3 / \text{min}$ (normal) supply of the argon gas were carried out, and the pressure was held to 2×10^{-1} Pa. Then, substrate temperature was heated at 200°C , electrical connection was changed to the target of the zinc oxide of 6 inchphi, the direct current power of 100W was impressed for 100 minutes, and about 2000-nm zinc oxide layer was deposited. Thus, by the same procedure as the working example 1, the photovoltaic cell was produced except having produced the intermediate layer. This sample was made into "the ratio 6."

[0155]

The result of having estimated the intermediate layer's thickness distribution as the working

example 1 similarly is shown in Table 22. The normal of the flat surface which three points adjacent in each point within a field make from the height information acquired by AFM makes the altitude of a substrate, and the angle to make an angle of inclination, and an average tilt angle averages them in a field here.

[0156]

Each average thickness was 2.0 micrometers. The sample of real 6A, real 6B, and real 6C was carrying out form of island shape, and the thickness of the portion which makes the circumference of island shape was 50% or less of average thickness. The sample of the ratio 6 had not carried out form of island shape, although there was unevenness. It checked that the indium oxide deposited for the use of the mask was removed from the sample of real 6A, real 6B, and real 6C being thinner than the thickness which the greatest thickness deposited in the sputtering.

[0157]

[Table 21]

	光入射側の面の 平均傾斜角(°)	その反対側の面の 平均傾斜角(°)
比6	10.7	13.7
実6A	13.5	13.7
実6B	16.8	13.6
実6C	18.3	13.9

[0158]

Next, the current potential characteristic of the produced optoelectric transducer was measured like the working example 1. The result is shown in Table 23. A relative value with the comparative example 6 shows a result.

[0159]

[Table 22]

表23	Jsc	FF	Voc	Eff.	Rsh
実6A/比6	1.002	1.032	1.017	1.052	3.12×10^2
実6B/比6	1.011	1.034	1.018	1.064	4.29×10^2
実6C/比6	1.012	1.033	1.015	1.061	4.55×10^2

[0160]

Although short circuit photoelectric current of real 6C and real 6B is increasing rather than the ratio 6, real 6A is hardly increasing. This result showed that it was alike rattlingly and photoelectric conversion efficiency was improving more with a larger average tilt angle of unevenness of Men of the light incidence side than the average tilt angle of unevenness of Men of that opposite hand.

[0161]

The spectral sensitivity characteristic was measured like the working example 5, and the short circuit photoelectric current of the 1st photoelectromotive-force layer and the short circuit photoelectric current of the 2nd photoelectromotive-force layer were searched for.

[0162]

The ratio [as opposed to / carry out sample Seki and / the comparative example 6 for a result] of three pieces of the working example 6 shows to Table 24.

[0163]

[Table 23]

	第1の光起電力層	第3の光起電力層
実6 A	1.001	0.996
実6 B	1.011	1.016
実6 C	1.012	1.019

[0164]

Although the short circuit photoelectric current of the 1st photoelectromotive-force layer and the short circuit photoelectric current of real 6C and real 6B of the 2nd photoelectromotive-force layer are increasing rather than the ratio 6, real 6A is hardly increasing.

[0165]

The above result showed that it is alike rattlingly, and dispersion of light increased more, absorption in a photoelectromotive-force layer increased, and photoelectric conversion efficiency was improving by the increase in short circuit photoelectric current with a larger average tilt angle of unevenness of Men of the light incidence side than the average tilt angle of unevenness of Men of the opposite hand.

[0166]

[Effect of the Invention]

As explained above, in this invention, by providing the intermediate layer of island shape in a lamination type photovoltaic cell, the influence of the defect which short circuit photoelectric current increased and was generated in the photoelectromotive-force layer is reduced, and good open circuit voltage and a curvilinear factor are obtained. Therefore, high photoelectric conversion efficiency is acquired. Cost can be reduced by Kami who manufactures since the influence of a defect can be reduced easily.

[Brief Description of the Drawings]

[Drawing 1] It is a mimetic diagram showing the concept of the intermediate layer of island shape.

[Drawing 2] Although it is the same unevenness, it is a key map of an intermediate layer when average thickness is thick.

[Drawing 3] It is a mimetic diagram of the course of the leakage current in case a defect exists in a photoelectromotive-force layer.

[Drawing 4] It is a schematic view showing typically the section structure of one embodiment of the lamination type photovoltaic cell of this invention.

[Drawing 5] It is a schematic view showing typically the section structure of other one embodiments of the lamination type photovoltaic cell of this invention.

[Drawing 6] except for not having the intermediate layer -- the lamination type photovoltaic cell of this invention -- it is a schematic view showing typically the section structure of the lamination type photovoltaic cell of the same composition.

[Drawing 7] Since the semiconductor layer of the lamination type photovoltaic cell of this invention is deposited, it is a mimetic diagram showing one form of suitable equipment.

[Explanations of letters or numerals]

101 The boundary of an island

102 Island

103 The portion which makes the circumference of an island

104 The intermediate layer of island shape
105 Photoelectromotive-force layer
106 50% of line of average thickness
201 Intermediate layer
202 Photoelectromotive-force layer
203 50% of line of average thickness
301 The intermediate layer of island shape
302 Photoelectromotive-force layer
303 Defect
304 The portion which makes the circumference of an island
305 Island
306 Leakage current
402 Reflecting layer
403 The 2nd photoelectromotive-force layer
404 Intermediate layer
405 The 1st photoelectromotive-force layer element
406 Transparent electrode
501 Substrate
502 Reflecting layer
503 The 2nd photoelectromotive-force layer
504 Intermediate layer
505 The 1st photoelectromotive-force layer
506 Transparent electrode
601 Substrate
602 Reflecting layer
603 The 2nd photoelectromotive-force layer
604 The 1st photoelectromotive-force layer element
605 Transparent electrode
701 Load chamber
702 N layer chamber
703 Micro crystallite i layer chamber
704 Amorphous i layer chamber
705 p layer chamber
706 Unloading chamber
707, 708, 709, 710, and 711 Gate valve
712 The heater for micro crystallite i layer board heating
713 Micro crystallite i layer plasma-CVD room
714 The heater for n layer board heating
715 N layer plasma-CVD room
716 The heater for amorphous i layer board heating
717 i layer plasma-CVD room
718 The heater for p layer board heating
719 p layer plasma-CVD room
720 Electrode-holder carrying rails
721 Substrate holder

[Translation done.]